NEUTRAL MASS SPECTROMETER MEASUREMENTS IN THE SHUTTLE BAY ENVIRONMENT

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Abstract. A neutral mass spectrometer, flown as part of the Induced Environment Contamination Monitor (IECM), is briefly described. Results from STS-2, -3, -4, and Spacelab 1 are qualitatively summarized. The gases observed were, for the most part, those with molecular weights below 45 amu with sources attributable to instrument background, shuttle-induced environment, and the ambient atmosphere. The most abundant gases were H_2O, N_2, and He. Heavier gases consisted primarily of fluorocarbons.

Introduction

A neutral mass spectrometer was flown as part of the Induced Contamination Monitor (IECM) on shuttle flights STS-2, -3, -4, and Spacelab 1 [Miller, 1983a,b, 1984] (Figure 1). It will also fly on Spacelab 2. The mass spectrometer covered the mass range from 2-150 amu with a nominal resolution of 1 amu over the range. The instrument field-of-view was collimated by a three-stage skimmer to 0.1 sr (Figure 2). Gas entering at angles greater than 10° to the view axis are skimmed into a matrix of zirconium oxide getters where active atoms and molecules are pumped providing the collimation. Nonreactive gases such as helium and argon are not pumped by these getters and thus are not collimated.

In normal operation, a 600-s cycle format was employed during which each mass number from 2 to 150 amu was sampled for 2 s and during the subsequent 300 s, mass 18 (H_2O) was sampled continuously with a 2-s integration period. Other formats, selectable by the astronauts, reduced the integration period to 0.2 s and/or truncated the mass range to 2-50 amu. With both options selected the mass range from 2-50 was sampled each 10 s. The instrument was sealed in an ultra-clean vacuum prior to launch and opened to the environment after the shuttle was in orbit.

The IECM was mounted in the payload bay such that the view axis of the mass spectrometer was along the -Z axis. On STS-2, -3, and -4, with the bay doors open, there was very little shuttle surface in the entire 2π front hemisphere, so that virtually all arriving contaminant gases were scattered from atmospheric gases. Interpretation of the arriving flux in terms of its source strength or column density thus involves consideration of the scattering cross section of the 8 km/s collisions between contaminants and the atmosphere. On STS-4, the IECM was grappled by the Remote Manipulator Arm and a survey was made with

the instrument axis looking back in toward the bay and wing surfaces. On Spacelab 1 the IECM was located well below the sill line so that much of the aft bulkhead and instrument surfaces were within the uncollimated field-of-view.

The IECM and the mass spectrometer functioned well on all four flights. There were some anomalies and minor problems, but for the most part, operation was nominal. The quantitative interpretation of the mass spectrometer measurements was expected to be difficult and it has been. The major limitation of the spectrometer measurements has been the relatively large background of previously pumped gases over the zirconium oxide getters. Despite the difficulties and the limitations of the system, some success has been achieved in characterizing the gaseous environment in the vicinity of the shuttle.

Results

A qualitative summary of the measurements will be presented here describing the interpretation of the gaseous contributors to each of the mass numbers from 2-44 and a few others at greater mass number.

Mass 2--Molecular hydrogen that is almost entirely background of the zirconium oxide getters. No significance can be attached to the mass 2 measurement.

Mass 3--Statistically insignificant (SI).

Mass 4--Helium. This is the best measurement made by the instrument. There is virtually zero background contribution at mass 4. Helium is not collimated or otherwise affected by the getters and so the instrument field-of-view is 2π sr. Atmospheric helium is observed and its quantification is in good agreement with model values on all flights. Helium is also a major contaminant of the shuttle (10^{-9} torr on Spacelab 1) and is observed even in the wake [Naumann et al., 1985].

Mass 5--SI.

Mass 6--SI.

Mass 7--SI.

Mass 8--SI.

Mass 9--SI.

Mass 10--SI.

Mass 11--Small but statistically significant; possibly borane.

Mass 12--All carbon bearing molecules contribute to this peak.

Mass 13--Mostly a product of dissociative ionization of CH_4. This peak together with 14, 15, and 16 is used to separate methane from other contributors to these mass numbers.

Mass 14--A complex sum of doubly and dissociatively ionized N_2, doubly ionized CO, and dissociatively ionized CH_4. Its abundance is heavily modulated by angle of attack because of the N_2 contribution and is also modulated by methane producing events.

Mass 15--Almost exclusively from methane; a very small fraction from the 15 isotope in nitrogen compounds. It is the mass of choice for quantifying the methane source density because it is uncontaminated by atomic oxygen and is almost equally sensitive of methane as the mass 16 peak.

Mass 16--Methane and atomic oxygen. Ambient atomic oxygen does not survive the many surface collisions before ionization. It combines to form CO, CO_2, and O_2. The contribution to the mass 16 peak is thus indirect through dissociative ionization of oxygen bearing molecules. Methane is a substantial background gas over the zirconium oxide getters. It also appears to be catalytically produced in the instrument from some effluent associated with thruster firings. It is postulated that it is formed on the getter surfaces by conversion of unoxidized or partially oxidized thruster fuel, monomethyl hydrazine.

Mass 17--Dissociatively ionized H_2O, i.e., $OH+$. The amplitude of the mass 17 peak is about 40 percent of the mass 18 peak due to water.

Mass 18--Water. The density of H_2O; in the ion source is the sum of the instrument background and contaminant H_2O from various shuttle sources. In most observation geometries, the contaminant H_2O observed is the consequence of scattering by the ambient atmosphere into the instrument orifice, giving source densities of about $10^7/cm^3$ and column densities of $10^{12}/cm^2$.

Mass 19--A statistically significant but unknown contaminant. It is possibly an ionization product of a fluorine compound, but the associated spectral peaks have not been identified.

Mass 20--Mostly doubly ionized argon with a small contribution from the oxygen 18 isotope in H_2O. A small impurity in the neon 22 used for calibration is observed during calibrations.

Mass 21--Statistically insignificant except during calibration using isotopically labeled neon. Neon 22 was used for the calibration; contributions at masses 20 and 21 resulted from impurities and, in the case of mass 21, a slight cross-talk from the large mass 22 peak.

Mass 22--Doubly ionized CO_2, except during calibration when the isotopically labeled neon 22 caused count rates in excess of $2 \times 10^6/$ 2 s at mass 22.

Mass 23--SI.

Masses 24, 25, 26, and 27--Small, but measurable, products of an instrument contaminant of unidentified origin.

Mass 28--Molecular nitrogen (ambient and contaminant) and carbon monoxide which is a relatively large instrument background over the zirconium oxide getters and other metal surfaces. At small angles of attack the mass 28 peak is dominated by streaming ambient molecular nitrogen, and the quantitiative interpretation of the peak yields reasonable values for ambient density. During the contamination survey taken on STS-4 with the IECM looking into the payload bay the fluxes of molecular nitrogen appear to be about half that of water. This would lead to a column density for N_2 contaminant of $1.0 \times 10^{12}/cm^2$. The survey also showed that the major N_2 contamination source was in the vicinity of the aft bulkhead (Figure 3).

Mass 29--Mostly N_2 with one atom of nitrogen 15.

Mass 30--Probably NO with large peaks observed during thruster firings.

Mass 31--Not analyzed.

Mass 32--Molecular oxygen mostly of atomspheric origin through the recombination of atomic oxygen. The level of molecular oxygen contamination is very low, probably below the instrument background.

Mass 33--SI.

Mass 34--Not analyzed; partly O_{16}-O_{18}.

Mass 35--SI.

Mass 36--An unknown minor contaminant, possibly HCl, plus a small component of argon 36.

Masses 37, 38, 39, 41, and 42--Small but statistically significant peaks characteristic of propene.

Mass 40--Argon. Analysis of the mass 40 peak at low angles of attack yields reasonable values for ambient argon densities. There is an argon contaminant on at least some of the flights. The STS-3 door closing event showed a steep rise in mass 40.

Mass 44--CO_2. Mostly instrument background with some small contribution from the shuttle that is too low with respect to background to quantify.

Masses 50, 81, and 100--Fractionation spectrum of C_2F_4 (tetrafluoroethene) observed on Spacelab 1 flight.

Masses 85, 87, 101, 103, 125, and 137--Fractionation spectrum of freon 114, $C_2Cl_2F_4$ from a known 6.2 cm^3/day leak in the Spacelab cooling loop on Spacelab 1.

Masses 67 and 69--The principal peaks of electron impact-inoized Freon 21, $CHCl_2F$, are presumably from a leak in the shuttle cooling loop. Strong signatures of Freon 21 were observed on STS-4 during the contamination survey and during the payload bay door cycling events.

References

Miller, E. R. (editor), STS-2, -3, -4 Induced Environment Contamination Monitor (IECM) Summary Report, NASA TM-82524, 1983a.

Miller, E. R., Update of Induced Environment Contamination Monitor Results, presented at AIAA Shuttle Environments and Operations Meeting, Washington, D.C., 1983b.

Miller, E. R. (editor), Induced Environment Comtamination Monitor - Preliminary results from the Spacelab 1 flight, NASA TM-86461, 1984.

Naumann, R. J., G. R. Carignan, and E. R. Miller, Space Shuttle molecular scattering and wake vacuum measurements, Journal of Vacuum Science and Technology, in press, 1985.

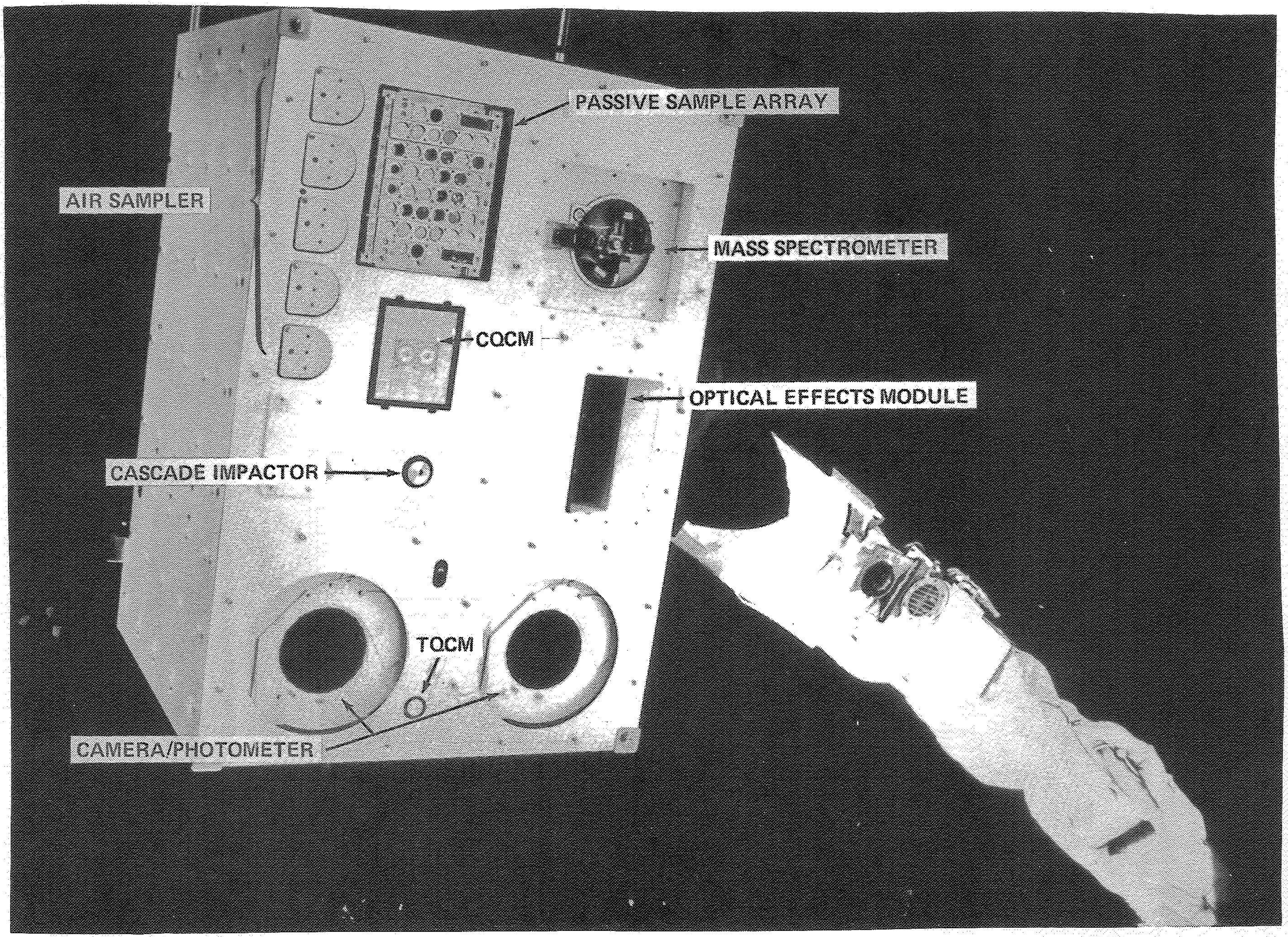

Fig. 1. IECM during remote contamination survey.

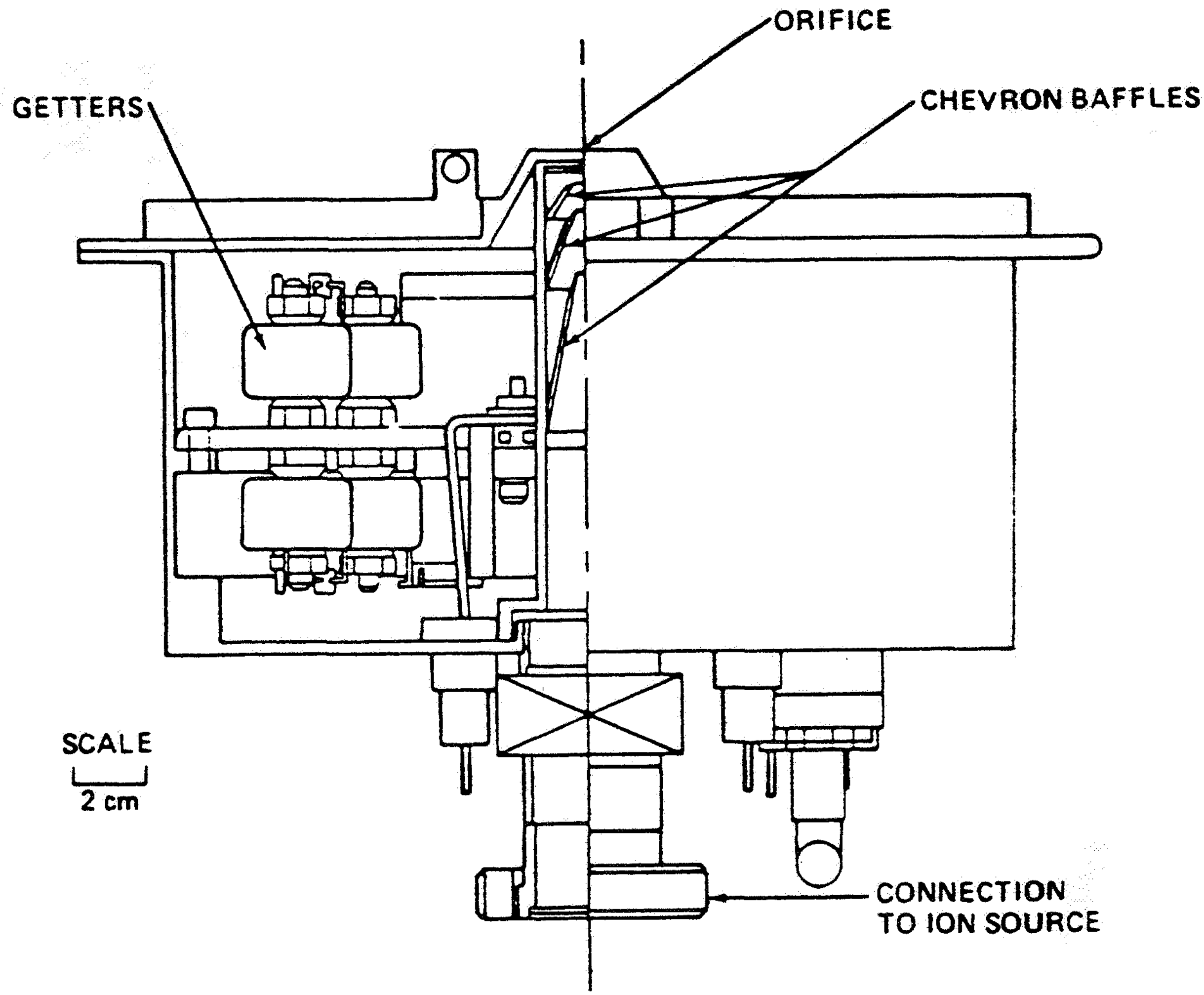

Fig. 2. Mass spectrometer collimator.

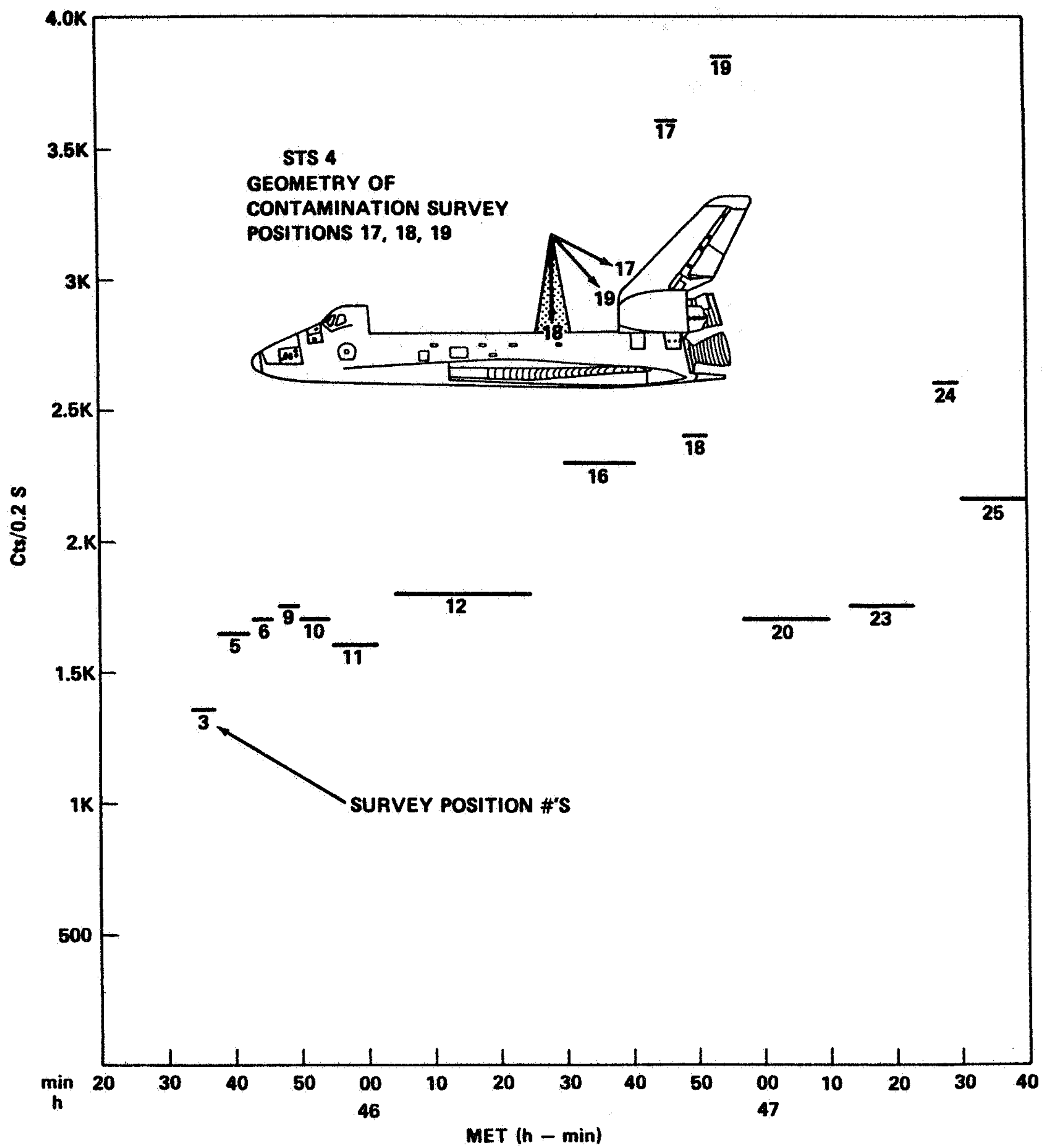

Fig. 3. Mass 28 during the remote contamination survey on STS-4.